Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

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Guidance for Estimating Naphthalene and Polycyclic Organic Matter Emissions from Transportation Projects

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TABLE OF CONTENTS

Section **Page**

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

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1. INTRODUCTION

For many years, the U.S. Environmental Protection Agency (EPA) has estimated that mobile sources (e.g., cars and trucks) account for a large fraction of all cancers attributed to outdoor sources of air toxics. In 2001, EPA identified six priority mobile source air toxics (MSATs): acetaldehyde, acrolein, benzene, diesel exhaust components (diesel particulate matter [DPM] and diesel exhaust organic gas [DEOG]), formaldehyde, and 1,3-butadiene. In a February 26, 2007, MSAT final rule, EPA also identified naphthalene and a group of other polycyclic organic matter (POM) compounds[1] as important MSATs. The U.S. Federal Highway Administration (FHWA) published project-level MSAT assessment guidance in February 2006, and in September 2009 FHWA updated its federal guidance for completing project-level MSAT analyses to include naphthalene and POM. Therefore, as part of transportation planning and project analyses, Caltrans project analysts must determine potential MSAT impacts from transportation projects. To comply with the updated FHWA guidance, analysts need an approach for estimating project-level naphthalene and POM emissions.

This technical document provides interim guidance to estimate on-road vehicular naphthalene and POM emissions from transportation projects. This guidance is meant to help estimate emissions until such time as either the California Air Resources Board (CARB) or EPA provides more detailed information. The guidance describes a six-step method to estimate project-specific emissions based on project-level particulate matter (PM) and total organic gas (TOG) emissions from the CT-EMFAC[2] model and EPA's on-road mobile source speciation[3] information for naphthalene and POM. This methodology enables project analysts to derive naphthalene and POM emissions from CT-EMFAC, which is the same information source used to estimate emissions of other MSATs for California transportation project assessments.

This guidance document is organized into the following sections: Section 2 provides a brief introduction to the speciation information for naphthalene and POM; Section 3 presents step-by-step instructions for estimating naphthalene and POM emissions from transportation projects based on CT-EMFAC results; Section 4 illustrates a project-level analysis example for calculating naphthalene and POM emissions. The document also includes several appendices with specific speciation data and technical details for estimating project-level naphthalene and POM emissions.

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[1] EPA's definition of POM as a priority MSAT pollutant includes the following 15 compounds (listed in alphabetical order): acenaphthene, acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, phenanthrene, and pyrene. See Table III. C-2 in EPA's 2006 notice of proposed rule making (Federal Register, Control of Hazardous Air Pollutants from Mobile Sources; Proposed Rule, March 29, 2006; http://www.epa.gov/otaq/regs/toxics/msat-nprm-fr.pdf).

[2] CT-EMFAC is a California-specific project-level analysis tool for modeling on-road vehicular emissions of criteria pollutants, MSATs, and carbon dioxide. The tool's underlying emission factor information is based on the CARB EMFAC2007 on-road emissions model and MSAT speciation factors provided by CARB (for acetaldehyde, acrolein, benzene, formaldehyde, and 1,3-butadiene). As of this writing, the latest version of CT-EMFAC does not output emissions estimates for naphthalene and POM. Please see CT-EMFAC's documentation report (Wu et al., 2007) for a more complete discussion of the model.

[3] Speciation refers to the fraction of an overall pollutant category (such as PM_{10} and TOG) that is comprised of a particular compound. For example, if naphthalene emissions are estimated to be 8% of total PM_{10} emissions, a 0.08 speciation factor for naphthalene can be used as a multiplier to estimate naphthalene emissions once PM_{10} emissions are known.

2. SPECIATION INFORMATION FOR NAPHTHALENE AND POM

Motor vehicles contribute to naphthalene emissions through both incomplete fuel combustion and fuel evaporation; POM compounds mainly result from incomplete fuel combustion and occur primarily as airborne particles. As of this writing, chemical speciation information for estimating naphthalene and POM emissions from mobile sources is limited. CARB documents the fraction of reactive organic gas (ROG) that is naphthalene; however, the information is available only for a limited range of gasoline vehicles, and detailed speciation information for naphthalene and POM is still under development (Hughes, 2010). Because of this lack of complete speciation data, California modeling tools (e.g., EMFAC and CT-EMFAC) do not directly output emissions estimates for naphthalene and POM. This guidance, therefore, uses data from EPA to construct an emissions estimation method.

EPA has estimated the fraction of PM mass emitted by on-road vehicles that is equal to naphthalene and 15 other POM compounds (see Appendix A). These fractions, referred to as "mass ratios" (similar to speciation factors used in CT-EMFAC for modeling the six priority MSAT pollutants), have been used in the EPA's National Mobile Inventory Model (NMIM) as defaults for the development of naphthalene and POM emissions in the EPA National Emissions Inventory (NEI). The mass ratios were estimated by EPA as fractions of exhaust PM_{10} emissions by fuel type (gasoline and diesel). Evaporative naphthalene emissions from motor vehicles were estimated as a fraction of total volatile organic compound (VOC) emissions. The methodology described in this guidance document involves developing naphthalene and POM multipliers based on the EPA's NMIM mass ratio data, and then applying those multipliers to the project-level PM_{10} and TOG emissions output from CT-EMFAC.

3. GUIDANCE FOR ESTIMATING NAPHTHALENE AND POM EMISSIONS

The following material describes a step-by-step procedure to estimate naphthalene and POM emissions for a California project-level MSAT analysis. As illustrated in **Figure 3-1**, the procedure consists of six steps:

1. Identify the percentage of truck traffic and other required input data for the CT-EMFAC model
2. Run CT-EMFAC to obtain project PM_{10} and TOG emissions estimates
3. Identify the fraction of diesel truck traffic within the total truck fleet for the project
4. Identify multipliers for naphthalene and POM emissions using a lookup table
5. Identify an average VOC/TOG ratio for the project area
6. Calculate project-level naphthalene and POM emissions

Project analysts will typically need to repeat the above analysis steps for various studied scenarios, such as an existing condition scenario, build and no-build scenarios for an operational year, and build and no-build scenarios for a horizon planning year.

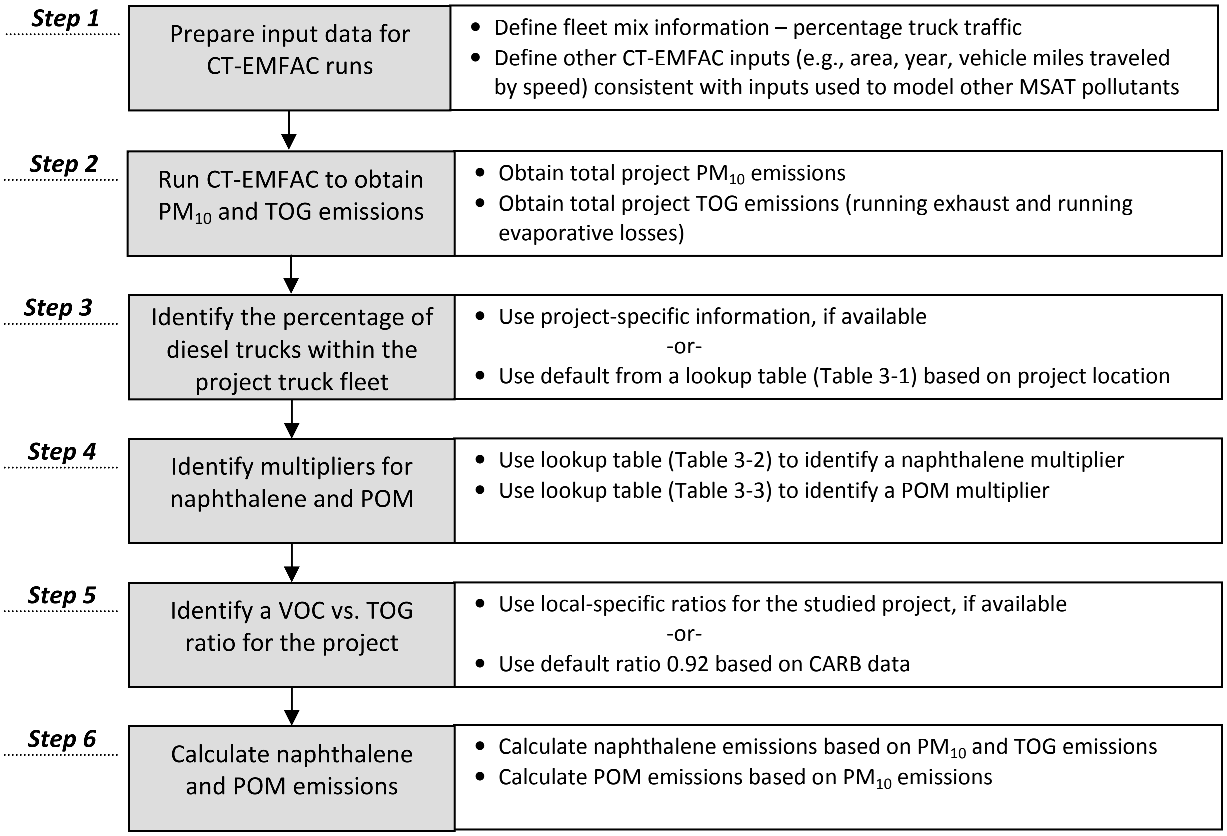

Figure 3-1. Step-by-step procedure for estimating project-level naphthalene and POM emissions.

Step 1: Prepare input data for CT-EMFAC runs

In the first step, a project analyst prepares all required input data for a CT-EMFAC model run. The required input parameters mainly include geographic area, analysis year, season, vehicle mix, and travel activities associated with the studied project. Detailed descriptions for the preparation of these input data are available in the CT-EMFAC model document (Wu et al., 2007). These input data should be the same as those used for estimating other project-level emissions directly from CT-EMFAC. Note that a key input is the percentage of total project volumes (or vehicle miles) that is comprised of truck volumes (or vehicle miles).

Step 2: Run CT-EMFAC to obtain PM_{10} and TOG emissions

After all input information required for the project is prepared, the project analyst selects PM_{10} and TOG (along with other pollutants of interest) in the CT-EMFAC user interface to generate total PM_{10} and TOG emissions estimates. For a project-level MSAT assessment, emissions estimates for PM_{10}, TOG, and the six MSAT pollutants should be included in one CT-EMFAC run. This will ensure that the same input data are used to develop emissions estimates for all of the pollutant species.

Step 3: Identify the percentage of diesel truck traffic within the project truck fleet

In this step, the project analyst estimates the fraction of diesel vehicles within the truck fleet specific to the project's geographic region. Project-specific diesel fraction information should be used, if available. If project-specific data are not available, then **Table 3-1** can be used to identify a default diesel vehicle fraction for the project. Note that the fraction of diesel-powered vehicles is not the same as the fraction of vehicles that are trucks. Many trucks are gasoline-powered. If users are unsure of the diesel truck fraction for their area, they should use the data in **Table 3-1**. The fraction of diesel vehicle volume (or miles traveled) within the truck fleet varies by region. For example, the diesel vehicle miles traveled (VMT) for medium-duty and above trucks (the truck fleet defined in CT-EMFAC) are approximately 20% and 50% in Amador County and Fresno County, respectively, according to CARB's EMFAC2007 model. Based on the geographic location of the project, the project analyst can use **Table 3-1** to identify a default value for the percent of diesel truck traffic within the project truck fleet by state, air basin, or county.

Table 3-1. Default diesel fractions within the truck fleet in California air basins and counties.

Geographic Area	Diesel Fraction in Truck Fleet	Geographic Area	Diesel Fraction in Truck Fleet	Geographic Area	Diesel Fraction in Truck Fleet
State		**County**		**County**	
State Average	30%	Imperial	70%	Sacramento	30%
Air Basin		Inyo	50%	San Benito	70%
Great Basin Valleys (GBV)	50%	Kern	60%	San Bernardino	40%
Lake County (LC)	30%	Kern (MD)	60%	San Bernardino (MD)	60%
Lake Tahoe (LT)	20%	Kern (SJV)	60%	San Bernardino (SC)	30%
Mojave Desert (MD)	60%	Kings	70%	San Diego	20%
Mountain Counties (MC)	40%	Lake	30%	San Francisco	30%
North Central Coast (NCC)	30%	Lassen	20%	San Joaquin	40%
North Coast (NC)	40%	Los Angeles	30%	San Luis Obispo	30%
Northeast Plateau (NP)	60%	Los Angeles (MD)	20%	San Mateo	20%
Sacramento Valley (SV)	40%	Los Angeles (SC)	30%	Santa Barbara	20%
Salton Sea (SS)	60%	Madera	50%	Santa Clara	30%
San Diego County (SDC)	20%	Marin	20%	Santa Cruz	20%
San Francisco Bay (SFB)	30%	Mariposa	20%	Shasta	50%
San Joaquin Valley (SJV)	50%	Mendocino	50%	Sierra	30%
South Central Coast (SCC)	20%	Merced	60%	Siskiyou	70%
South Coast (SC)	30%	Modoc	30%	Solano	40%
County		Mono	50%	Solano (SFB)	30%
Alameda	40%	Monterey	30%	Solano (SV)	40%
Alpine	70%	Napa	30%	Sonoma	30%
Amador	20%	Nevada	40%	Sonoma (NC)	40%
Butte	50%	Orange	20%	Sonoma (SFB)	20%
Calaveras	30%	Placer	30%	Stanislaus	40%
Colusa	70%	Placer (LT)	20%	Sutter	50%
Contra Costa	20%	Placer (MC)	80%	Tehama	70%
Del Norte	20%	Placer (SV)	20%	Trinity	60%
El Dorado	20%	Plumas	20%	Tulare	40%
El Dorado (LT)	20%	Riverside	40%	Tuolumne	20%
El Dorado (MC)	20%	Riverside (MD/MDAQMD)	90%	Ventura	20%
Fresno	50%	Riverside (MD/SCAQMD)	100%	Yolo	40%
Glenn	60%	Riverside (SC)	30%	Yuba	20%
Humboldt	40%	Riverside (SS)	50%		

Note: The *diesel fraction* represents the percentage of diesel truck VMT among medium-duty and above truck VMT for a geographic area. Percentage data shown in the table were developed based on CARB's EMFAC2007 model default VMT distributions by vehicle class (averaged across years 2002 to 2040 and assigned to the closest percentage bin). The geographic areas listed in the table (overall state, air basins, and counties) are consistent with the options provided in the CT-EMFAC user interface (some counties, such as Los Angeles and Riverside, are located in multiple air basins and therefore have multiple percentage values for all related air basins).

Step 4: Identify multipliers for naphthalene and POM emissions

Based on *% trucks* and *% diesel within the truck fleet* identified in Step 1 and Step 3, respectively, the project analyst would identify multipliers for exhaust naphthalene and POM emissions. The multipliers in this guidance document represent weighted average mass ratios derived from the NMIM speciation data and are provided in two lookup tables (**Tables 3-2** and **3-3**). Details regarding how the multipliers were developed are presented in Appendix B.

Table 3-2. Multipliers for estimating exhaust naphthalene emissions.

	% Diesel within the truck fleet										
% Trucks	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
0%	0.0880	0.0880	0.0880	0.0880	0.0880	0.0880	0.0880	0.0880	0.0880	0.0880	0.0880
10%	0.0880	0.0872	0.0863	0.0855	0.0846	0.0838	0.0829	0.0821	0.0813	0.0804	0.0796
20%	0.0880	0.0863	0.0846	0.0829	0.0813	0.0796	0.0779	0.0762	0.0745	0.0728	0.0711
30%	0.0880	0.0855	0.0829	0.0804	0.0779	0.0754	0.0728	0.0703	0.0678	0.0652	0.0627
40%	0.0880	0.0846	0.0813	0.0779	0.0745	0.0711	0.0678	0.0644	0.0610	0.0576	0.0543
50%	0.0880	0.0838	0.0796	0.0754	0.0711	0.0669	0.0627	0.0585	0.0543	0.0501	0.0458
60%	0.0880	0.0829	0.0779	0.0728	0.0678	0.0627	0.0576	0.0526	0.0475	0.0425	0.0374
70%	0.0880	0.0821	0.0762	0.0703	0.0644	0.0585	0.0526	0.0467	0.0408	0.0349	0.0290
80%	0.0880	0.0813	0.0745	0.0678	0.0610	0.0543	0.0475	0.0408	0.0340	0.0273	0.0205
90%	0.0880	0.0804	0.0728	0.0652	0.0576	0.0501	0.0425	0.0349	0.0273	0.0197	0.0121
100%	0.0880	0.0796	0.0711	0.0627	0.0543	0.0458	0.0374	0.0290	0.0205	0.0121	0.0037

Table 3-3. Multipliers for estimating POM emissions.

	% Diesel within the truck fleet										
% Trucks	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
0%	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124
10%	0.0124	0.0123	0.0122	0.0122	0.0121	0.0120	0.0119	0.0118	0.0118	0.0117	0.0116
20%	0.0124	0.0122	0.0121	0.0119	0.0118	0.0116	0.0114	0.0113	0.0111	0.0109	0.0108
30%	0.0124	0.0122	0.0119	0.0117	0.0114	0.0112	0.0109	0.0107	0.0105	0.0102	0.0100
40%	0.0124	0.0121	0.0118	0.0114	0.0111	0.0108	0.0105	0.0101	0.0098	0.0095	0.0092
50%	0.0124	0.0120	0.0116	0.0112	0.0108	0.0104	0.0100	0.0096	0.0092	0.0088	0.0083
60%	0.0124	0.0119	0.0114	0.0109	0.0105	0.0100	0.0095	0.0090	0.0085	0.0080	0.0075
70%	0.0124	0.0118	0.0113	0.0107	0.0101	0.0096	0.0090	0.0084	0.0079	0.0073	0.0067
80%	0.0124	0.0118	0.0111	0.0105	0.0098	0.0092	0.0085	0.0079	0.0072	0.0066	0.0059
90%	0.0124	0.0117	0.0109	0.0102	0.0095	0.0088	0.0080	0.0073	0.0066	0.0058	0.0051
100%	0.0124	0.0116	0.0108	0.0100	0.0092	0.0083	0.0075	0.0067	0.0059	0.0051	0.0043

Step 5: Identify VOC vs. TOG ratios for the project

To estimate evaporative naphthalene emissions, the project analyst identifies a VOC vs. TOG ratio for the studied project. The ratio is used to estimate the VOC fraction of TOG emissions provided by CT-EMFAC. The NMIM mass ratio for evaporative naphthalene can be applied directly to the VOC fraction. A default VOC/TOG ratio of 0.92 is recommended based on California statewide emissions inventory data (i.e., approximately 92% of total TOG emissions from on-road motor vehicles are VOC or reactive organic gas [ROG] emissions).[4] More information regarding the development of the default VOC/TOG ratio is described in Appendix C. If other VOC/TOG ratios are available and project-specific, analysts should replace this default with local information. However, because evaporative emissions account for

[4] Based on CARB data available at http://www.arb.ca.gov/app/emsinv/emssumcat.php (2009 Almanac Emission Projection Data), from on-road motor vehicles, California's statewide ROG emissions are approximately 91-92% of TOG for calendar years 2008, 2010, 2015, and 2020. As a conservative estimate, the methodology includes an assumption that 92% of TOG emissions equal either ROG or VOC.

a very small proportion of total emissions for naphthalene, the impact of using different VOC/TOG ratios is minor.

Step 6: Calculate project-level naphthalene and POM emissions

In this step, the project analyst uses Equation 1 and Equation 2 to calculate total project-level naphthalene and POM emissions.

$$\boldsymbol{Naphthalene = PM_{10} \times m_{naphthalene} + TOG \times (VOC/TOG\ ratio) \times evapGas\ ratio} \qquad \text{(Equation 1)}$$

where,

Naphthalene	= total project-level naphthalene emissions.
PM_{10}	= total project-level PM_{10} emissions from CT-EMFAC (see Step 2).
$m_{naphthalene}$	= naphthalene multiplier (obtained from **Table 3-2** based on *% trucks* and *% diesel within the truck fleet*; see Step 4).
TOG	= total project-level TOG emissions from CT-EMFAC (see Step 2).
VOC/TOG ratio	= VOC emissions to TOG emissions ratio (default = 0.92; see Step 5).
evapGas ratio	= 0.0004 (based on NMIM speciation data for evaporative naphthalene emissions from gasoline-powered vehicles; see Appendix A).

$$\boldsymbol{POM = PM_{10} \times m_{POM}} \qquad \text{(Equation 2)}$$

where,

POM	= total project-level POM emissions.
PM_{10}	= total project-level PM_{10} emissions from CT-EMFAC (see Step 2).
m_{POM}	= POM multiplier (obtained from **Table 3-3** based on *% trucks* and *% diesel within the truck fleet*; see Step 4).

4. ILLUSTRATION OF A PROJECT-LEVEL ANALYSIS EXAMPLE FOR NAPHTHALENE AND POM EMISSIONS

A hypothetical project scenario is presented below to illustrate the application of the six-step approach for estimating naphthalene and POM emissions as part of a project-level MSAT emissions assessment. The assumed scenario is associated with build conditions in a planning horizon year 2030 for a transportation project located in Los Angeles County within the South Coast Air Basin. It is further assumed that, for this scenario, medium-duty and above trucks account for approximately 10% of the total 300,000 daily VMT, including both trucks and non-trucks, traveling at an average speed of 65 miles per hour on the studied roadway segments.

In Step 1, based on the project scenario information, the following input parameters can be specified for a CT-EMFAC run:

- Geographic Aea = County, Los Angeles (SC)
- Analysis Year = 2030
- Season = Annual
- Vehicle mix = 10% trucks and 90% others
- Total daily VMT = 300,000 miles (allocated to the 65 mph speed bin)

In Step 2, PM_{10}, TOG, and the six priority MSAT pollutants are selected for a complete MSAT emissions assessment using the CT-EMFAC model. Given the input parameters specified in Step 1, CT-EMFAC generates total daily project-level emissions for PM_{10} (5,942 grams) and TOG (20,600 grams).

In Step 3, **Table 3-1** is used to identify a default proportion of diesel truck traffic within the project truck fleet. Since the project is located in Los Angeles County in the South Coast Air Basin, the default percentage of diesel truck traffic within the total truck fleet is approximately 30%.

In Step 4, **Tables 3-2** and **3-3** are used to identify multipliers for exhaust naphthalene and POM emissions. The mass ratio values for naphthalene and POM multipliers associated with *10% trucks* and *30% diesel within the truck fleet* are 0.0855 and 0.0122, respectively. The mass ratio for evaporative naphthalene emissions is 0.0004.

In Step 5, given that no project-specific VOC/TOG ratios are available, the default value of 0.92 is used for the project scenario, which assumes that VOC emissions account for 92% of the TOG emissions estimated by CT-EMFAC.

In Step 6, based on Equation 1 and Equation 2, the total project naphthalene and POM emissions are:

$$
\begin{aligned}
\textit{Naphthalene} &= PM_{10} \times m_{naphthalene} + TOG \times (VOC/TOG\ ratio) \times evapGas\ ratio \\
&= 5{,}942 \times 0.0855 + 20{,}600 \times (0.92) \times 0.0004 \\
&= 516\ grams/day
\end{aligned}
$$

$$
\begin{aligned}
\textit{POM} &= PM_{10} \times m_{POM} \\
&= 5{,}942 \times 0.0122 \\
&= 73\ grams/day
\end{aligned}
$$

5. REFERENCES

Wu P., Bai S., Eisinger D., and Niemeier D. (2007) CT-EMFAC: a computer model to estimate transportation project emissions. Prepared for the California Department of Transportation, Division of Transportation Planning, Sacramento, CA, by the UC Davis-Caltrans Air Quality Project, Davis, CA, Task Orders No. 61 and 67, December 10.

Hughes V. (2010) Personal communication with Vernon Hughes, California Air Resources Board.

APPENDIX A. NMIM MASS RATIOS FOR NAPHTHALENE AND POM

EPA's National Mobile Inventory Model (NMIM) includes speciation information in the form of PM_{10} mass ratios for exhaust naphthalene emissions, VOC mass ratios for evaporative naphthalene emissions, and PM_{10} mass ratios for exhaust emissions of 15 POM compounds. As shown in **Table A-1**, the mass ratios for exhaust emissions are specified for gasoline- and diesel-powered vehicles. For example, the NMIM speciation data suggest that exhaust naphthalene emissions are equal to about 8.8% and 0.37% of PM_{10} emissions for a typical gasoline vehicle and for a typical light-duty diesel vehicle, respectively. The evaporative naphthalene emissions from a gasoline vehicle are equal to approximately 0.04% of its VOC emissions.

Table A-1. Mass ratios of naphthalene and POM in the NMIM database.

Pollutant Name	exhGas[a]	exhDiesel[b]		evapGas[c]	Ratio Type[d]
		Light-duty	Heavy-duty		
Naphthalene	**0.088005400**	**0.003662920**	**0.00128892**	**0.0004**	**PM_{10} (exhGas and exhDiesel), and VOC (evapGas)**
POM (15 pollutants)					
Acenaphthene	0.000709119	0.000085500	0.000022080	n/a	PM_{10}
Acenaphthylene	0.003993460	0.000970960	0.000034040	n/a	PM_{10}
Anthracene	0.000821085	0.000181721	0.000034040	n/a	PM_{10}
Benz(a)anthracene	0.000099500	0.000048100	0.000036800	n/a	PM_{10}
Benzo(a)pyrene	0.000099500	0.000044500	0.000011960	n/a	PM_{10}
Benzo(b)fluoranthene	0.000118186	0.000078400	0.000010120	n/a	PM_{10}
Benzo(g,h,i)perylene	0.000248814	0.000053400	0.000008280	n/a	PM_{10}
Benzo(k)fluoranthene	0.000118186	0.000078400	0.000010120	n/a	PM_{10}
Chrysene	0.000099500	0.000057000	0.000006440	n/a	PM_{10}
Dibenz(a,h)anthracene	0.000000000	0.000001780	0.000000000	n/a	PM_{10}
Fluoranthene	0.000883288	0.000536255	0.000020240	n/a	PM_{10}
Fluorene	0.001468000	0.000381258	0.000045080	n/a	PM_{10}
Indeno(1,2,3-c,d)pyrene	0.000074600	0.000021400	0.000000920	n/a	PM_{10}
Phenanthrene	0.002463260	0.001058260	0.000051520	n/a	PM_{10}
Pyrene	0.001206750	0.000689471	0.000035880	n/a	PM_{10}
POM Total	**0.012403248**	**0.004286405**	**0.000327520**	**n/a**	**PM_{10}**

Source: National Mobile Inventory Model Software and Documentation (http://nsdi.epa.gov/otaq/nmim.htm).

[a] Mass ratios for exhaust emissions from gasoline-powered vehicles.

[b] The NMIM database includes mass ratios for MSAT pollutants that vary by fuel type (gasoline vs. diesel). The ratios are also different between light-duty diesel trucks and heavy-duty diesel trucks; to be conservative, the methodology described in this document uses the ratios associated with light-duty diesel trucks presented in this table (i.e., this will generate higher naphthalene and POM emissions estimates) when developing the naphthalene and POM multipliers (weighted average of mass ratios for gasoline and diesel vehicles).

[c] Mass ratio for evaporative naphthalene emissions from gasoline-powered vehicles.

[d] The ratio type refers to the MSAT pollutant (naphthalene or POM) as a fraction of total mass-based emissions of either PM_{10} or VOC. These ratios, according to NMIM, are independent of vehicle model year or calendar year.

APPENDIX B. MULTIPLIERS FOR NAPHTHALENE AND POM EMISSIONS

The methodology described in this guidance document uses CT-EMFAC emissions output and speciation data included in the EPA's NMIM database to develop project-level naphthalene and POM emissions. This approach enables use of a single set of nationally approved data for naphthalene and the 15 other POM pollutants; it also avoids the problem of trying to extrapolate potential emissions from the limited literature currently available. The methodology can be revised over time as more data become available.

The CT-EMFAC model provides total project emissions for PM_{10} and TOG associated with a user-specified fleet mix (i.e., percentage of medium-duty and above trucks), in which gasoline and diesel sources are not distinguished. Therefore, to combine fuel-specific NMIM mass ratios (see **Table A-1**) and CT-EMFAC results for estimating naphthalene and POM emissions, the following data processing is conducted to develop weighted average mass ratios, or multipliers, for naphthalene and POM.

Given a project-specific fleet mix (*% trucks*) and an estimated diesel fraction within the total truck fleet (*% diesel*), a weighted average mass ratio (see Equation B-1) is developed for exhaust naphthalene or POM using the NMIM data included in **Table A-1**. This average mass ratio can be used as a multiplier to calculate exhaust naphthalene and POM emissions based on PM_{10} emissions estimates from CT-EMFAC. For this calculation, it is assumed that the diesel travel is contributed by only the truck fleet (medium-duty and above trucks) and that all non-trucks are gasoline-powered vehicles.

$$m_{naphthalene} \text{ or } m_{POM} = (\%\ trucks)\times(\%\ diesel)\times exhDiesel\ ratio + [1-(\%\ trucks)\times(\%\ diesel)]\times exhGas\ ratio \qquad \text{(Equation B-1)}$$

where,

$m_{naphthalene}$	= multiplier for naphthalene
m_{POM}	= multiplier for POM
% trucks	= percentage of volume or VMT from medium-duty and above trucks (used in CT-EMFAC runs)
% diesel	= percentage of diesel truck volume or VMT within the truck fleet
exhDiesel ratio	= NMIM mass ratio for exhaust emissions from light-duty diesel vehicles (in **Table A-1**, column "exhDiesel, Light-duty")
exhGas ratio	= NMIM mass ratio for exhaust emissions from gasoline vehicles (in **Table A-1**, column "exhGas")

The multipliers calculated based on Equation B-1 are included in a lookup table by *% trucks* and *% diesel* associated with the studied project (see **Tables 3-2** and **3-3**). For example, given a 10% truck fleet and 30% of trucks that are diesel, the multipliers for estimating exhaust naphthalene and POM emissions are:

$$m_{naphthalene} = 10\% \times 30\% \times 0.003662920 + [1-(10\%)\times(30\%)]\times 0.088005400 = 0.0855$$

$$m_{POM} = 10\% \times 30\% \times 0.004286405 + [1-(10\%)\times(30\%)]\times 0.012403248 = 0.0122$$

APPENDIX C. DEVELOPMENT OF VOC VS. TOG RATIOS

The NMIM mass ratio for evaporative naphthalene emissions (see Appendix A) is associated with VOC, while CT-EMFAC (and EMFAC) express hydrocarbons as TOG. Based on the EMFAC2007 User's Guide, the TOG class includes all organic gases emitted into the atmosphere; the majority are ROG (or VOC, by EPA's definition).[5] For emissions estimation using EMFAC, CARB specifies that the ROG class is the same as EPA's VOC definition.

CARB 2009 Almanac Emission Projection Data includes emissions inventories for TOG and ROG for multiple calendar years in various areas of California. **Table C-1** summarizes CARB's TOG and ROG emissions estimates for statewide and major air basins for years 2008, 2010, 2015, and 2020. Approximately 91% to 92% of total TOG emissions from on-road motor vehicles in California are ROG (or VOC) emissions. For estimating evaporative naphthalene emissions from transportation projects, a default ratio of 0.92 is identified in the methodology described in this guidance to convert CT-EMFAC TOG emissions results to VOC emissions.

Table C-1. California on-road mobile source TOG and ROG emissions.

Geographic Area	Calendar Year	TOG (ton/day)	ROG (ton/day)	ROG (or VOC) vs. TOG Ratio
California statewide	2008	692.8	632.4	0.913
	2010	608.1	555.0	0.913
	2015	455.9	416.8	0.914
	2020	364.3	334.3	0.918
Sacramento Valley Air Basin	2008	60.0	55.1	0.918
	2010	53.1	48.8	0.919
	2015	39.4	36.3	0.921
	2020	31.2	28.8	0.923
San Diego Air Basin	2008	56.2	51.0	0.907
	2010	49.1	44.5	0.906
	2015	37.8	34.4	0.910
	2020	31.5	28.8	0.914
San Francisco Bay Area Air Basin	2008	122.6	112.3	0.916
	2010	106.3	97.4	0.916
	2015	77.9	71.6	0.919
	2020	61.9	57.0	0.921
San Joaquin Valley Air Basin	2008	87.0	79.2	0.910
	2010	78.6	71.5	0.910
	2015	57.9	52.7	0.910
	2020	45.2	41.3	0.914
South Coast Air Basin	2008	231.8	210.8	0.909
	2010	201.1	182.8	0.909
	2015	152.9	139.2	0.910
	2020	123.3	112.8	0.915

Source: CARB 2009 Almanac Emission Projection Data (http://www.arb.ca.gov/app/emsinv/emssumcat.php).

[5] See the document at http://www.arb.ca.gov/msei/onroad/downloads/docs/user_guide_emfac2007.pdf (page 4). More information on the differences between EPA and CARB hydrocarbon definitions is available via the Internet (see: http://www.epa.gov/otaq/models/nonrdmdl/p03002.pdf for EPA information and http://www.arb.ca.gov/ei/speciate/voc_rog_dfn_1_09.pdf for CARB information). For purposes of estimating evaporative naphthalene emissions, this methodology embeds a simplified assumption consistent with EMFAC documentation that ROG and VOC are approximately the same.